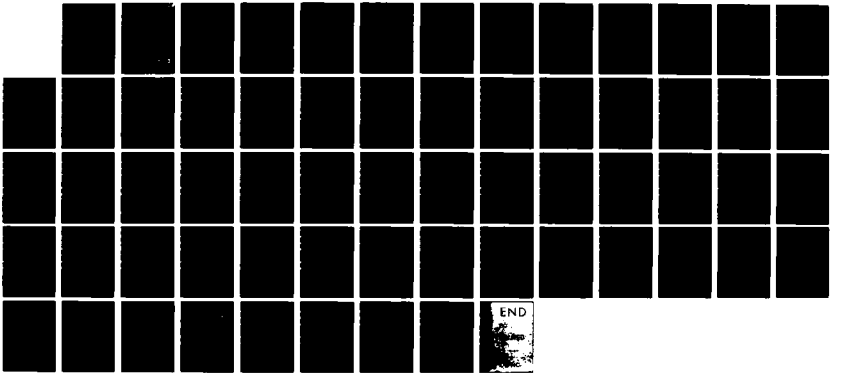
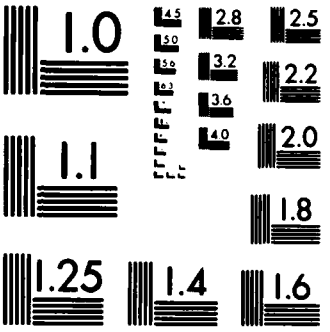
AD-A148 054 THE EFFECTS OF A WARMING BLANKET AND WARMED INTRAVENOUS CRYSTALLOID ON PA.. (U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH R E MCCAIN AUG 84 1/1

UNCLASSIFIED AFIT/CI/NR-84-88T F/G 6/12 NL





UNCLASS

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

# REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

| | |
|---|---|
| 1. REPORT NUMBER: AFIT/CI/NR 84-88T | 2. GOVT ACCESSION NO. |
| 3. RECIPIENT'S CATALOG NUMBER | |
| 4. TITLE (and Subtitle): The Effects Of A Warming Blanket And Warmed Intravenous Crystalloid On Patient Temperature During Surgery Not Involving A Body Cavity | 5. TYPE OF REPORT & PERIOD COVERED: THESIS/DISSERTATION |
| | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s): Robert E. McCain | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS: AFIT STUDENT AT: Virginia Commonwealth University | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS: AFIT/NR WPAFB OH 45433 | 12. REPORT DATE: Aug 1984 |
| | 13. NUMBER OF PAGES: 49 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) | 15. SECURITY CLASS. (of this report): UNCLASS |
| | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

APPROVED FOR PUBLIC RELEASE: IAW AFR 190-1

9 Nov 84

LYNN E. WOLAVER
Dean for Research and
Professional Development
AFIT, Wright-Patterson AFB OH

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

ATTACHED

DTIC ELECTE NOV 29 1984 S D E

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASS

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

84 11 15 016

AD-A148 054

DTIC FILE COPY

# THE EFFECTS OF A WARMING BLANKET AND WARMED INTRAVENOUS CRYSTALLOID ON PATIENT TEMPERATURE DURING SURGERY NOT INVOLVING A BODY CAVITY

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at Virginia Commonwealth University

by

Robert E. McCain, B.S.N.

Director: Salvatore A. Ciresi
C.R.N.A., M.S.

Virginia Commonwealth University
Richmond, Virginia
August, 1984

# ACKNOWLEDGEMENTS

It is with gratitude that the following are formally recognized as having contributed in various ways to aid in the completion of this study:

a) Oscar Aghdami, M.D.

b) Thomas Kinahan, C.R.N.A., M.S.

c) Charles Moore, C.R.N.A., M.S.

Particular gratitude is expressed to Kathleen McCain for her faithful assistance and support.

# TABLE OF CONTENTS

Chapter 4

# ABSTRACT

THE EFFECTS OF A WARMING BLANKET AND WARMED INTRAVENOUS CRYSTALLOID ON PATIENT TEMPERATURE DURING SURGERY NOT INVOLVING A BODY CAVITY

Robert E. McCain, B.S.N.

Medical College of Virginia, Virginia Commonwealth University, 1984

Major Director: Salvatore Ciresi, C.R.N.A., M.S.

The purpose of this study was to determine the effectiveness of the warming blanket, warmed intravenous crystalloid, and a combination of both heating modalities in the maintenance of normothermia in the anesthetized adult undergoing surgery not involving a body cavity.

Twenty-eight patients were included in this quasi-experimental study. They were adults between the ages of 18 and 75. All were normothermic prior to surgery. The patients required general oral endotracheal tube inhalation or narcotic anesthesia for a minimum of two hours.

Participants in the study were randomly assigned to one of four groups:

Group 1 (Control).....No externally applied heating modality was used.

Group 2 (Experimental).....One externally applied heating modality was used: warming blanket.

Group 3 (Experimental).....One externally applied heating modality was used: warmed intravenous crystalloid.

Group 4 (Experimental).....A combination of two externally applied heating modalities were used: warming blanket and warmed intravenous crystalloid.

Routine induction of general anesthesia and subsequent intubation were performed. Immediately after intubation, esophageal temperature monitoring began. Measurements were read at the nearest 0.1 degree celsius ( °C). Subsequently, every 15 minutes the temperature was read and recorded.

When the data collection was completed, there were statistically significant differences between the control and the experimental groups. Statistical analysis using regression analysis, a method for estimating the amount of variation of a dependent variable which can be explained by an independent variable, was applied.

The results indicated that subjects not exposed to any externally applied heating modality did experience a statistically significant decrease in esophageal temperature with increasing time. Those subjects managed with either warmed crystalloid or a warming blanket did not demonstrate a statistically significant increase or decrease in esophageal temperature with time. The esophageal temperatures in these groups remained essentially unchanged with increasing time. The subjects managed with a combination of warmed intravenous crystalloid and the warming blanket showed a statistically significant increase in esophageal temperature with increasing time.

In conclusion, this study demonstrated that the esophageal temperature of the anesthetized adult who underwent surgery not

involving a body cavity decreased significantly with increasing time when externally applied heating modalities were not used. The study also demonstrated that the esophageal temperature of the anesthetized subject remained essentially unchanged with increasing time when either warmed crystalloid or a warming blanket were used. Those subjects who were managed with a combination of warmed crystalloid and a warming blanket demonstrated a significant increase in esophageal temperature with increasing time.

This study indicates that to increase a patient's core temperature during the course of a general anesthetic, the use of a combination of warmed intravenous crystalloid and a warming blanket contributes to goal attainment. It is desired to prevent a decrease in core temperature during a general anesthetic. Therefore, use of either warmed intravenous crystalloid or a warming blanket will prevent such a decrease.

(Key Words: Body Core Temperature, Esophageal Thermister Probe, Hypo/Hyperthermia Blanket, Warmed Intravenous Crystalloid)

# CHAPTER 1

## INTRODUCTION

Though Hippocrates distinguished temperature variation by placing his hand upon the patient's breast, actual measurements of temperature were first undertaken by Sanctorious early in the seventeenth century (Cranston, 1966). During the next 200 years measurements were seldom reported. In 1797 James Currie, a Fellow of the Royal College of Physicians of Edinburgh wrote: "If a definition of life were required, it might be most clearly established on that capacity by which the animal preserves its proper heat under the various degrees of temperature in which it finds itself." (Cranston, 1966). Thus, the general biological importance of the regulation of temperature had long been recognized before Claude Bernard (1879) used temperature regulation as a principle example of modulation of the internal environment of the body.

The human being of the 20th century can easily find himself within the ultra-sophisticated environment of the medical center operating theater. This environment is indeed a challenge to the temperature regulation coping mechanisms of the human being.

There are several factors making temperature regulation difficult. Patients frequently become hypothermic (body temperature less than 36°C) during surgical procedures in modern air-conditioned operating rooms. Heat loss during anesthesia occurs not only because of low environmental temperatures and humidity but also because of

the infusion of cold fluids, ventilation of cold gases, the exposure of body cavities, the absence of muscle movement, and subcutaneous vasodilatation (Morris, 1971; Holdcroft, 1978; Crocker, et al., 1980; Dyde, et al., 1970; Carli, et al., 1970).

The data from several studies indicate that adverse effects of hypothermia include postoperative increase in oxygen consumption, decreased oxygen availability, increase in pulmonary arterial and systemic vascular resistance, diminished membrane excitability, decreased drug biotransformation, an increased incidence of deep venous thrombosis, and pulmonary embolism (Harrison, et al., 1967; Tausk, et al., 1976; Pflug, et al., 1978; and Holdcroft, et al., 1978).

The heat loss that occurs during anesthesia is regained after surgery by a combination of shivering and vasoconstriction. Bay, Nunn and Prys-Roberts (1977) measured the oxygen consumption in patients shivering after surgery and found increases of 135-468% over basal values. These enormous increases in oxygen consumption impose a further burden on a cardio-respiratory system which may already be depressed after prolonged anesthesia. If sufficient oxygen is not delivered to the muscle to maintain aerobic metabolism, anaerobic pathways are activated. The undesirable effect of anaerobic metabolism is the production of lactate, or lactic acidosis (Gilbert, 1983). Thus, the maintenance of normothermia during anesthesia prevents an undesirable increase in oxygen consumption during and after surgery. Additionally, normothermia during and after the surgical procedure decreases the possibility of encountering the many

other adverse effects of hypothermia: 1) decreased mixed venous oxygen saturation, 2) delayed tissue enzyme reactions, 3) decreased tissue perfusion resulting from a lefthand shift of the oxyhemoglobin dissociation curve, and 4) decreased cerebral perfusion (Gronert, 1983; Flacke, 1983).

The major issue under investigation in previous thermoregulation studies has been the effect of operating room ambient temperature on patient temperature. Few studies have specifically focused on the effects of warmed crystalloid alone or a combination of warmed crystalloid and the warming blanket on intraoperative patient temperature.

## Purpose of the study

The purpose of this investigation was to determine the effectiveness of the warming blanket, warmed intravenous crystalloid, and a combination of both heating modalities in the maintenance of normothermia in the anesthetized adult undergoing surgery not involving a body cavity.

## Statement of the Problem

Does the intraoperative use of a warming blanket, warmed intravenous crystalloid, or a combination of both heating modalities prevent the development of hypothermia in the anesthetized adult undergoing surgery not involving a body cavity?

## Hypothesis

This study examined the following hypothesis:

The use of warmed intravenous crystalloid fluids in combination with intraoperative use of a warming blanket will be more effective in maintaining a steady state temperature than either method used independently.

## Variables

1. Independent Variables - There were two independent variables: (1) a warming blanket and (2) warmed intravenous crystalloid.

2. Dependent Variable - The dependent variable was patient core temperature as measured by an esophageal temperature probe.

## Definition of Terms

For the purpose of this study, the following definitions were used:

Intraoperative - that time period in which the patient was in direct physical contact with the operating room table.

Warming blanket - an electrically controlled device which circulated water at a temperature of 40°C through a rubber mattress pad placed between the operating room table and the patient.

Warmed intravenous crystalloid - Lactated Ringer's injection or

dextrose 5% in Lactated Ringer's injection warmed through coils in an electrically heated bath of water at a temperature of 35°C.

Hypothermia - a temperature below 36°C as measured in the distal 1/4 of the esophagus.

Anesthetized adult - an individual between 18 and 75 years of age experiencing general oral endotracheal anesthesia with a halogenated anesthetic gas, nitrous oxide, narcotics, and oxygen.

Surgery not involving a body cavity - surgery not involving entrance into the abdominal, thoracic, or cranial cavities.

Baseline temperature - esophageal temperature measurement recorded immediately after induction of general anesthesia.

## Assumptions

There were three basic assumptions of the study:

1. Change in body temperature could accurately be measured in the distal 1/4 of the esophagus.

2. Body tissue acted as a heat conducting medium.

3. Environmental temperature was not manipulated by the researcher beyond the modalities of warmed intravenous crystalloid and the warming blanket in order to maintain near normal anesthetic conditions.

## Limitations

The limitations of the study were as follows:

1. The length of time each patient was exposed to the operating room environment prior to surgical draping varied with each surgical procedure.

2. There was no control over variations in individual basal metabolic rates.

3. There was no control over extent of body surface area exposed to the operating room environment during the surgical procedure.

## Delimitations

The delimitations of the study were as follows:

1. The data was collected at one Southeastern United States medical center.

2. Data was collected between March and June, 1984.

3. Sample size was limited to 28.

4. One specific esophageal temperature measuring device was used in the study.

## Theoretical Framework

The most common theory of the central control of body temperature assumes a fixed "set point" of body temperature and that

any change in the internal environmental temperature away from this "set point" initiates either heat producing or heat dissipating mechanisms. It is postulated that this "set point" may change, for example in exercise or in response to pyrogens (Benzinger, 1969).

When the body temperature of man is considered, a distinction must be made between the temperature inside the body (the core temperature) and that at the periphery (the body shell temperature). The body shell temperature fluctuates considerably as a function of the ambient temperature. The core temperature, however, must be held constant.

The adult human regulates core temperature by two main mechanisms: the control of heat production and the control of heat loss. Thermoregulatory production of extra heat in adults is achieved primarily via the somatomotor system - by shivering, which in turn accelerates metabolism. Heat loss is regulated by control of the cutaneous circulation. The heat generated in the body is transported by the bloodstream to the skin and given off to the environment (Hall, 1978).

There are two centers in the hypothalamus concerned with temperature regulation, an anterior, temperature sensitive area (Aronsohn-Sachs center) and a posterior, temperature insensitive area (Krehl-Isenschmidt center) (Downey, et al., 1967). Cold impulses from the periphery meet in the posterior center and this area initiates increases in heat production by shivering. The cold receptors in the skin commence firing at a temperature of 33 °C and the frequency increases to a maximum at a skin temperature of 20°C.

However, if the core temperature is normal or increased, this is detected by the temperature sensitive neurons of the anterior center, which inhibit the posterior center from stimulating heat production. Under this theory of control of temperature, there is no thermogenesis until the core temperature is below normal, regardless of the skin temperature (Taylor, 1963).

Heat is lost from the body by the physical processes of evaporation, radiation, conduction, and convection (Schmidt, 1978; Brobeck, 1979). Some 80% or more of this heat transfer occurs through the skin. The rest takes place through the mucous membranes of the respiratory, digestive, and urinary tracts.

Evaporation (0.58 kilocalories per milliliter evaporated water) may vary between a few kilocalories per hour (kcal/hr) to 400 kcal/hr dependent on the amount of evaporation from the organs in the abdomen or thorax during surgery. Heat energy must be expended to evaporate any fluid. Evaporation of fluid, therefore, constitutes one method by which heat is lost from the body, especially from the skin. Cold prep solutions prior to surgical draping enhance evaporative heat loss. At moderate temperatures it accounts for about half as much heat loss as does radiation.

Radiation is the transfer of heat from the surface of one object to that of another without actual contact between the two. Heat radiates from the body surface to nearby operating room equipment that is cooler than the skin. Radiative heat loss acounts for about 36 kcal/hr in a naked resting man in an environmental temperatre of 20°C.

Conduction means the transfer of heat to any substance actually in contact with the body. This process accounts for a relatively small amount of heat loss compared to the amount lost by evaporation and radiation. Conductive heat loss, the infusion of fluids and body structures in contact with the operating room table, varies between a few kcal/hr and several hundred kcal/hr (Guyton, 1974).

Convection is the transfer of heat away from a surface by movement of air or fluid particles. Convection heat loss varies between a few kcal/hr to 15 kcal/hr. Usually convection causes very little heat loss from the body's surface, but, depending upon air flow, can be a considerable contribution to body cooling.

To maintain normothermia, the anesthetist must prevent or replace the heat lost by evaporation, radiation, conduction, and convection. Measures which have been used in an attempt to prevent body heat loss by these physical processes include heat lamps, thermal blankets, warmed intravenous fluids, humidified anesthetic gases, and warmed blankets on exposed skin surfaces. Each measure has limits to it's ability to prevent heat loss.

# Literature Review

Environmental hypothermia occurs with regularity under general anesthesia because mammals become poikilothermic; they assume the temperature of their environment (Lunn, 1969; Goldberg, 1966; Morris, 1971; Vaughn, 1981). Temperature falls if heat loss is greater than heat production, as is generally the case in cool operating rooms. This can be modified by the use of heated, humidified inspired gases, heated intravenous fluids, heat lamps, a warm room or a heated mattress under the patient (Gronert, 1983).

## Pathogenesis and Incidence of Temperature Fall During Anesthesia

Factors initiating hypothermia include the following: (1) immobility (unconsciousness) or removal of behavioral protection; (2) depression of the thermostat with consequent absence of initiation of autoregulatory compensatory mechanisms; (3) autonomic and/or motor blockade with impairment of heat generation; (4) vasodilatation; (5) wetting of the skin surface, and (6) exposure to a low ambient temperature. All of these increase heat transfer to the environment. As all of these factors are undoubtedly present to a greater or lesser extent during modern anesthesia and surgery, it is no surprise that hypothermia is almost inevitable. Deeply anesthetized patients are truely poikilothermic and even lightly anesthetized, paralyzed patients have a narrowed range over which they can maintain their temperature. Air conditioned operating rooms generally have temperatures between 18°C and 21°C (61 degrees Fahrenheit and 70

degrees Fahrenheit). A study carried out in England established that the majority of surgeons were most comfortable with operating room temperatures of 65 degrees Fahrenheit (°F) or less, relative humidity of less than 50%, and operating room air changes 25 times per hour or greater (Wyon, et al., 1968). Unfortunately, this was a very efficient system for promoting loss of heat from the patient's exposed areas, be they skin or large visceral surfaces (Roe, 1971). Further cooling may be promoted by inspiration of unheated, dry anesthetic gases. Cold dry gases are heated and humidified by the patient prior to expiration. Cooling may also be promoted by the administration of varying quantities of unwarmed fluids and blood products. Thus, it is no wonder that patients do become cold during general anesthesia.

Vaughn et al. (1981) studied 198 adult patients undergoing a variety of elective surgical procedures with both general and regional anesthetic management. Upon admission to the recovery room, their average tympanic (Dickey, et al., 1970; Webb, 1973) temperature was 35.6°C. Sixty percent of the patients had temperatures less than 36°C, and 13% were less than 35°C. Patients older than 65 years and undergoing major surgical procedures had the lowest temperatures. Intraoperative conditions such as room temperature, type of anesthesia circuit, thermal blanket use, and the administration of cold fluids and/or blood were not specified. The extensive studies of Morris (1970, 1971, 1971, 1972) demonstrated that all anesthetized patients become hypothermic when operated upon in rooms with temperatures less than 21 °C (70°F), regardless of whether thermal

blankets underneath the patients were used. Morris also found that the bulk of the drop in patient's temperatures occurred in the time prior to surgical incision during exposure and preparation. This fact has been confirmed by Ozuna (1978) and by Rozien (1980). An average intraoperative drop in temperature of 1.1°C was reported by Roe, et al. (1966) in a study of 24 adult patients, 83 percent sustained falls in rectal temperatures of 0.2°C or more. Lunn (1969) found decreases in deep body temperatures averaging 1.15°C during operations averaging 3.7 hours. These and other studies cited above demonstrate that body temperature falls in the majority of patients (Bennett, et al., 1977; Goudsouzian, et al., 1973).

## Prevention of Intraoperative Hypothermia

No one factor is responsible for the causes of body temperature cooling during a surgical procedure under general anesthesia. Hence, prevention is also multifaceted and consumes both time and attention.

In order to avoid intraoperative hypothermia, heat production must balance heat loss during anesthesia. In the resting awake state, basal oxygen consumption is about 130 milliliters per minute per meter squared (ml/min/m2) of body surface, providing a basal heat production of about one kcal/kg/hr (Bell, et al., 1980). This will, however, be considerably less in adequately anesthetized patients. For example, studies of oxygen consumption under anesthesia have shown that patients anesthetized with halothane (Eger, et al., 1970; Huang, et al., 1981; Huang, et al., 1981) or fentanyl (Huang, et al., 1981; Huang, et al., 1981) had oxygen consumptions of only 90 to 100

ml/min/m2 during the operative period. Another study (Huang, et al., 1981) measured oxygen consumptions of only 85 ml/min/m2 at the end of surgery in patients anesthetized with enflurane. Therefore heat production in these patients was of the order of only 0.6 kilocalories per kilogram per hour (kcal/kg/hr), which was only 42 kcal/hr in a 70-kg patient. In order to prevent intraoperative cooling, heat loss must be kept below this level. Each net loss of 58 kcal of heat results in a fall of 1°C in body temperature.

Heat losses occur from heat transfer both to the external environment and from transfer to cold fluids, blood, and/or gases that may have been given. Losses from intravenous fluids can be calculated as follows: 16 Kcal of heat per liter (L) of fluid infused at room temperature and 32 Kcal/L of blood infused at 4 °C. Therefore, with intraoperative crystalloid administration of 4 to 6 ml/kg/hr, this alone represents a heat loss of about 4.5 to 7 kcal/hr in a 70-kg patient, or from 11% to 16% of his heat production (Guyton, 1974).

Heat losses to a cooler external environment occur via conduction, radiation, convection, and possibly by evaporation. These losses can be diminished and prevented by ensuring that the environment is neither cooler nor drier than the body surfaces with which it is in contact. Measures advocated to insure this have included the use of heating lamps (Friedman, et al., 1967), placement of the patient on top of a warm-water mattress or other heating device (Lunn, 1969; Newman, 1971; Vale, 1973), encasement with other sorts of thermal garments (Goldblatt and Miller, 1972), and/or

plastic sheeting, cotton wadding, blankets, or metal impregnated reflective plastic drapes (Holdcroft, 1980; Vale, 1973). All of these measures, when properly executed, prevent heat loss. However, the effectiveness of warming devices varies greatly according to the degree with which they are in contact with the patient as well as to the temperature gradient between the patient and the adjacent material. For example, studies concerning the benefit of a warming mattress placed beneath the patient during surgery have shown that they are ineffective in maintaining body temperature unless other heat conserving measures were also taken (Morris, 1972). As Morris has pointed out, only about one third of a supine adult patient's body surface was in contact with the mattress. The temperature gradient between the mattress and patient was very small. Skin burns have been reported from the use of some of these devices (Crino and Nagel, 1968). Goudsouzian et al. (1973) found that water mattresses were of benefit and advocated their use, especially in the pediatric population. Goldblatt and Miller (1972) found that by encasing the entire patient in an anthropomorphically-shaped garment consisting of plastic tubes filled with warm water, prevention of heat loss was very effective. Vale (1973) has advocated the use of a prewarmed, heat-retaining mattress filled with methylcellulose gel as well as wrapping other non-surgical areas of the body in heat-reflecting blankets.

## Core Temperature Measurement in the Anesthetized Adult

There are a number of body sites at which body temperature can

be measured, only a few of which reflect core temperature effectively. Reitan (1978) has described the following as those sites used most frequently to monitor body temperature:

| | |
|---|---|
| Skin | Temperature varies with subcutaneous blood flow, sweating, radiation and conduction of heat to and from extracorporeal objects |
| Axilla | Temperature varies with blood flow |
| Muscle | Monitoring requires special probes; Temperature varies with blood flow |
| Rectum | Temperature varies with blood flow, fecal mass acts as an insulator |
| Pharyngeal and upper esophagus | Reflects temperature of respiratory gases; Nasal probes have the risk of producing epistaxis |
| Tympanic membrane | Closely approximates temperature of blood perfusing the brain when the probe is against the tympanic membrane; Discrepancies arise when the probe is located away from the membrane or impacted in cerumen, which acts as an insulator; Risks of membrane perforation and hemorrhage exist |
| Lower esophagus (20 cm below pharyngeoesophageal junction) | Measurement at this point closely approximates temperature of aortic blood (core temperature) |

| | |
|---|---|
| Pulmonary artery (Swan-Ganz thermodilution catheter) | This is not the primary purpose of the Swan-Ganz catheter, but it can be used to measure the temperature of blood in the body core |

The above measurements differ in the precision with which they reflect the temperature of the body core and in the complications of improper placement of the temperature probe.

Whitby and Dunkin (1969) suggest that to ensure complete immunity from respiratory effects, esophageal temperature leads should be placed 24 centimeters below the corniculate cartilages. They concluded that the temperatures in the upper half of the esophagus in the anesthetized patient were affected by intubation and ventilation. Those taken in the lower fourth were not. In their later report, Whitby and Dunkin (1971) produced further evidence that a lower esophageal temperature recording reflected core temperature with considerable accuracy. They confirmed that lower esophageal temperature readings provide an approximate indication of the cerebral temperature in the absence of an open thorax or a rapid transfusion of cold blood. Middle and upper esophageal recordings were unsatisfactory because of cooling from dry anesthetic gases.

In conclusion, the literature has clearly shown that one of the resultant problems of a general anesthetic is an alteration in the temperature regulating mechanism of the human body. Several methods have been used in previous studies to prevent a decrease in core temperature during general anesthesia. However, the effectiveness of a combination of warmed intravenous crystalloid and a warming blanket

has not been studies prior to this project. There is a need to evaluate available methods of preventing or replacing heat lost during surgery.

# CHAPTER 2

# METHODOLOGY

## Population, Setting and Sample

The sample was selected from adult male and female volunteers between the ages of 18 and 75 years. Each volunteer was scheduled for elective surgery not involving a body cavity under general anesthesia in a major Southeastern United States medical center. Data were collected between January and June, 1984.

The following criteria were used to exclude patients from the study:

1. Failure to provide consent;
2. Altered mental status sufficient to question an ability to cooperate;
3. Any surgical procedure involving a body cavity;
4. Surgical classification other than ASA I (normal healthy) and ASA II (mild systemic disease);
5. Known or suspected thermoregulation abnormalities;
6. Evidence of a febrile disease process within the past 72 hours.

## Research Design

This study was classified as a quasi-experimental design. In an

effort to have four groups as equal as possible, the subjects were randomly assigned to control or experimental groups. There was manipulation of the independent variables by the researcher. Esophageal temperatures of all groups were measured intraoperatively.

## Plan of Investigation

All subjects were interviewed preoperatively by a nurse anesthetist who ruled out the presence of exclusion criteria. Informed consent was obtained from each subject (Appendix A). Subjects were not informed of the treatment groups to which they were assigned. Subjects were numbered consecutively in the order in which they were anesthetized. Random assignment to either the control or one of the experimental groups was determined by random number generation using a Texas Instruments TI99/4A microcomputer.

Group I (control group) experienced no external heat supplying modalities during the surgical procedure. Group II (experimental group) experienced one externally applied heating modality - warmed intravenous fluids. Group III (experimental group) experienced one externally applied heating modality - a warmed heating blanket. Group IV (experimental group) experienced a combination of two externally applied heating modalities - warmed intravenous fluid and a warmed heating blanket were used.

Once in the operating room, all participants had an intravenous infusion of D5LR started with a Jelco intravenous catheter. Monitoring parameters for all four groups included an

electrocardiogram, a blood pressure monitor, and an esophageal temperature monitor.

All subjects underwent intravenous induction of general anesthesia, consisting of preoxygenation, precurarization, Sodium Pentothal, Succinylcholine, and endotracheal intubation. Routine anesthetic management was left to the discretion of the anesthetist or anesthesiologist. After endotracheal intubation, an esophageal temperature probe was inserted. Temperature was monitored and recorded immediately following intubation and at 15 minute intervals, to a maximum of two hours following the initial measurement (Appendix B). Patient safety was never compromised during this study. If, however, the safety of a patient had become compromised, the study of that patient would have been discontinued.

## Instrumentation

Four instruments were used in this study:

1. Gaynor Auto-Medi Therm, Automatic/Manual-Hyper/Hypothermia Unit, Model No. MTA-4700. Gaynor Industries, Inc., Orchard Park, New York. This solid state instrument with 500 watt heater provided distilled water to a hypo/hyperthermia pad heated to 38°C.

2. Synergy Temperature Monitor, Model No. 67N310. American Medical Systems, Division of American Hospital Supply Corporation, Cincinatti, Ohio. The temperature monitor operated by sensing a resistance change in the temperature probe and comparing that change to the calibration of the unit. The accuracy is ±.2 °C within the

operating temperature range of 34°C to 44°C.

3. Dupaco Hemokinetitherm Controlled Fluid Warmer. San Marcos, California. This instrument has two 150 watt heaters, proportional controller as primary control, and thermal switch as back-up control. Bath water was controlled at 35°C ±.5 C.

4. Critikon Jelco Esophageal Multi Probe II, 18 fr., 22 in. Tampa, Florida. This instrument is a temperature-sensitive nickle oxide resistor.

To assure reliability, the same equipment was used with each subject in this study.

## Plan of Data Analysis

Data was collected for statistical significance. Statistical analysis was performed using the regression analysis method. The independent variable was time and the dependent variable was esophageal temperature.

# CHAPTER 3

## RESULTS

The esophageal core temperature measurements of the control group were compared with the esophageal core temperature measurements of three experimental groups. In all groups, esophageal temperature measurements were made immediately post-intubation and at 15 minute intervals to a maximum of two hours post-intubation. There were seven subjects in each group, for a total of twenty-eight (n=28). The mean age of all participants was 47.2 years.

Anesthetic technique varied from case to case. All groups experienced general oral endotracheal tube inhalation or narcotic technique anesthesia. Anesthetic techniques used in this study are listed below (Table 1).

Table 1

Anesthetic Technique

| Primary agent | Numbers |
|---|---|
| Ethrane | 1 |
| Forane | 7 |
| Forane and Narcotic | 18 |
| Narcotic | 2 |
| TOTAL | 28 |

The surgical procedures included in this study are listed below (Table 2).

Table 2

Surgical Procedures

| | |
|---|---|
| ORTHOPEDIC | |
| Lower extremity | 8 |
| Upper extremity | 3 |
| Hip | 5 |
| GYNECOLOGY | |
| Total Vaginal Hysterectomy | 2 |
| GENERAL | |
| Parathyroidectomy | 1 |
| Skin Graft | 1 |
| Mastectomy | 2 |
| EAR, NOSE, THROAT | |
| Septoplasty | 2 |
| Mandible Resection | 1 |
| NEURO | |
| Cervical Laminectomy | 1 |
| VASCULAR | |
| Carotid Endarterectomy | 1 |
| Thrombectomy | 1 |

## GROUP 1: CONTROL

Group 1 consisted of 7 subjects with ages ranging from 22 to 44 years. The mean age was 35.1 years. Height in meters ranged from 1.68 to 1.85 with a mean of 1.79. Weight in kilograms ranged from 68 to 79 with a mean of 71.0. Body surface area in meters squared ranged from 1.81 to 2.02 with a mean of 1.89.

The mean ambient temperature was 20.4 ℃ with a range of 19.5 to 21.0 ℃. The mean baseline esophageal temperature was 36.1 ℃ and mean temperature at 120 minutes was 35.6 ℃. which constituted a 1.4% reduction in mean esophageal temperature over 2 hours (Appendix C).

## GROUP 2: WARMED INTRAVENOUS CRYSTALLOID

Group 2 consisted of 7 subjects with ages ranging from 28 to 63 years. The mean age was 49.8 years. Height in meters ranged from 1.55 to 1.88 with a mean of 1.74. Weight in kilograms ranged from 48 to 107 with a mean of 75.0. Body surface area in meters squared ranged from 1.44 to 2.20 with a mean of 1.88.

The mean ambient temperature was 20.1°C with a range of 19.5 to 20.5°C. The mean baseline esophageal temperature was 36.2°C and mean temperature at 120 minutes was 36.0 C. which constituted a 0.6% reduction in mean esophageal temperature over 2 hours (Appendix C).

## GROUP 3: WARMING BLANKET

Group 3 consisted of 7 subjects with ages ranging from 22 to 63 years. The mean age was 59.7 years. Height in meters ranged from 1.57 to 1.78 with a mean of 1.70. Weight in kilograms ranged from 57 to 104 with a mean of 75.7. Body surface area in meters squared ranged from 1.69 to 2.26 with a mean of 1.94.

The mean ambient temperature was 19.8°C with a range of 19.0 to 20.5°C. The mean baseline esophageal temperature was 36.1°C and mean temperature at 120 minutes was 35.7 °C. which constituted a 1.1% reduction in mean esophageal temperature over 2 hours (Appendix C).

GROUP 4: WARMED INTRAVENOUS CRYSTALLOID AND WARMING BLANKET

Group 4 consisted of 7 subjects with ages ranging from 45 to 75 years. The mean age was 59.7 years. Height in meters ranged from 1.57 to 1.78 with a mean of 1.70. Weight in kilograms ranged from 60 to 85 with a mean of 71.8. Body surface area in meters squared ranged from 1.60 to 2.03 with a mean of 1.83.

The mean ambient temperature was 20.1°C with a range of 19.0 to 21.0°C. The mean baseline esophageal temperature was 36.2°C and mean temperature at 120 minutes was 36.3°C. which constituted a 0.3% increase in mean esophageal temperature over 2 hours (Appendix C).

To determine the equality of groups, the One-Way Analysis of Variance (ANOVA) was used to examine the following variables:

1. Age across all groups
2. Height across all groups
3. Weight across all groups
4. Body surface area across all groups
5. Baseline esophageal temperature across all groups
6. Ambient temperature across all groups
7. Total intravenous fluids (ml) across all groups
8. Relative intravenous fluids (ml/kg) across all groups

There was a significant difference ($p < 0.025$) among the groups with respect to age. There was no significant difference among the groups with respect to each of the other variables.

Regression analysis was used to statistically analyze each of

the four groups. The independent variable in this method of analysis was time and the dependent variable in each group was esophageal temperature.

Regression of esophageal temperature on time in the control group explained a significant amount of the variation in the dependent variable ($p<0.001$). The slope of the regression equation was negative, and significantly different from zero, indicating that the esophageal temperature decreased with increasing time (Table 3).

Table 3

| | | |
|---|---|---|
| Group 1: Control | $F = 14.71$ | $df = 1, 61$ |
| | $r^2 = 0.194$ | $r = 0.44$ |
| | Slope: $-0.0040 \pm 0.0010$ | |

Regression of esophageal temperature on time in the warmed intravenous crystalloid group did not explain a significant amount of the variation in the dependent variable ($p>0.10$). The slope of the regression equation was negative, but not significantly different from zero, indicating that the esophageal temperature did not decrease with decreasing time (Table 4).

Table 4

| | | |
|---|---|---|
| Group 2: Warmed Intravenous Crystalloid | $F = 1.808$ | $df = 1, 61$ |
| | $r^2 = 0.029$ | $r = 0.054$ |
| | Slope: $-0.0013 \pm 0.0010$ | |

Regression of esophageal temperature on time in the warming blanket group did not explain a significant amount of the variation in the dependent variable ($p>0.10$). The slope of the regression equation was negative, but not significantly different from zero, indicating that the esophageal temperature did not decrease with increasing time (Table 5).

TABLE 5

| | | |
|---|---|---|
| Group 3: Warming Blanket | $F = 0.422$ | $df = 1, 61$ |
| | $r^2 = 0.007$ | $r = 0.084$ |
| | Slope: $-0.0017 \pm 0.0026$ | |

Regression of esophageal temperature on time in the group experiencing the combination of warmed intravenous crystalloid and warming blanket explained a significant amount of the variation in the dependent variable ($p<0.02$). The slope of the regression equation was positive, and significantly different from zero, indicating that the esophageal temperature increased with increasing time (Table 6).

Table 6

| | | |
|---|---|---|
| Group 4: Warmed Intravenous Crystalloid and Warming Blanket | $F = 6.291$ | $df = 1, 61$ |
| | $r^2 = 0.093$ | $r = 0.305$ |
| | Slope: $0.0016 \pm 0.0006$ | |

# CHAPTER 4

## DISCUSSION

This study demonstrated significant differences between three experimental groups and a control group with respect to temperature trends during general anesthesia. A core temperature increase existed in the group experiencing both warmed intravenous crystalloid and the warming blanket. An essentially unchanged core temperature was demonstrated in the groups receiving either warmed crystalloid or the warming blanket alone, while a decrease in core temperature was demonstrated in the control group. Analysis showed that correlation between an externally applied heating modality and maintenance of normothermia in the anesthetized subject was small but significant.

Analyzing other aspects of this study, it was demonstrated that core temperature decreased in the first 15 minute period following induction of general anesthesia. The core temperatures of 78.6 of the subjects decreased in the first 15 minute period following induction of general anesthesia regardless of externally applied heating modalities (Appendix D).

Although not analyzed in this study, the range of esophageal temperatures in the group experiencing the warming blanket alone was quite pronounced (34.2 - 37.4°C) when compared to the other groups (35.4 - 36.6 °C) (Appendix E). Perhaps an indication of margin of safety is implied. Some subjects in this group became very warm while others became very cold.

It is the conclusion of this researcher that the anesthetist must use all available means to prevent hypothermia during a general anesthetic. The results of this study are clear. The maintenance of normothermia during a general anesthetic will prevent many untoward intraoperative as well as postoperative complications. This researcher has shown that the most reliable means of maintaining normothermia during a surgical procedure not involving a body cavity is with the combined use of warmed crystalloid and a warming mattress.

Recommendations for further investigations of the effects of a warming blanket and warmed intravenous crystalloid on patient temperature during a general anesthetic would include:

1. A similar study with a larger sample;

2. A similar study with the inclusion of open cavity surgical procedures.

# REFERENCES

# REFERENCES

Bay J, Nunn JG, Prys-Roberts C. Factors influencing arterial Po2 during recovery from anaesthesia. British Journal of Anesthesia. 1968; 40:398-406.

Bell GH, Emslie-Smith D, Patterson CR. Textbook of Physiology. New York, Churchill Livingston, 1980, pp 12-18.

Bennett EJ, Patel KP, Grundy EM. Neonatal temperature and surgery. Anesthesiology. 1977; 36:303-304.

Benzinger M. Tympanic thermometry in surgery and anesthesia. Journal of the American Medical Association. 1969; 209:1207.

Bernard C. Lecons sur les phenomenes de la vie. Bailliere, Paris. 1879.

Brobeck JR. Physiological Basics of Medical Practice. Baltimore: Williams Wilkins, 1979.

Carli F, Clark MM, Woollen JW. Investigation of the relationship between heat loss and nitrogen excretion in elderly patients undergoing major abdominal surgery under general anaesthetic. British Journal of Anaesthesia. 1970; 54:1023-1028.

Cranston WI. Temperature regulation. British Medical Journal. 1966; 54:69-74.

Crino JH, Nagel EL. Thermal burns caused by warming blankets in the operating room. Anesthesiology. 1968; 29:149-150.

Crocker BD, Okumura F, McCraig DI, Denborough MA. Temperature monitoring during general anaesthesia. British Journal of Anaesthesia. 1980; 52:1223-1229.

Dickey WT, Ahlgren EW, Stephen CR. Body temperature monitoring via the tympanic membrane. Surgery. 1970; 67:981-984.

Downey JA, Miller JM, Darling RC. Thermoregulatory responses to deep and superficial cooling in spinal man. Journal of Applied Physiology. 1969; 27:209-212.

Dyde JA, Lunn HF. Heat loss during thoracotomy. Thorax. 1970; 25:355-358.

Eger EI, Smith NT, Stoelting RK, et al. Cardiovascular effects of halothane in man. Anesthesiology. 1970; 32:397-409.

Flacke JW, Flacke WE. Inadvertent hypothermia: Frequent, insidious, and often serious. Seminars in Anesthesia. 1983; 2:183-194.

Friedman F, Adams FH, Emmanouilides G. Regulation of body temperature of premature infants with low energy radiant heat. Journal of Pediatrics. 1967; 70:1-3.

Goldberg MJ, Roe CF. Temperature changes during anesthesia and operations. Archieves of Surgery. 1966; 93:365.

Goldblat A, Miller R. Prevention of incidental hypothermia in neurosurgical patients. Anesthesia and Analgesia. 1972; 51:536-543.

Gouc3ousian NG, Morris RH, Ryan JF. The effects of a warming blanket on the maintenance of body temperature in anesthetized infants and children. Anesthesiology. 1973; 39:351-353.

Gronert GA. Hypothermia - temperature correction - hyperthermia 1982 ASA Annual Refresher Course Lectures. American Society of Anesthesiologists. 1982.

Hall GM. Body temperature and anesthesia. British Journal of Anesthesia. 1978; 50:39-44.

Harrison MR, Hysing ES, Bo G. Control of body temperature: Use of respiratory tract as a heat exchanger. Journal of Pediatric Surgery. 1977; 12:821-828.

Holdcroft A. Body temperature control in anesthesia, surgery, and intensive care. London, Bailliere-Tindall, 1980.

Holdcroft A, Hall GM. Heat loss during anaesthesia. British Journal of Anaesthesia. 1987; 50:157-164.

Huang DH, Shigezawa GY, Sullivan SF. Vco2 Vo2 and RQ during inhalation anesthesia in man. Anesthesiology. 1981; 55:364.

Huang DH, Flacke JW, Law TS, et al. Oxygen uptake and delivery during halothane versus fentanyl anesthesia. Anesthesiology. 1981; 55:271.

Huang DH, Shigezawa GY, Gilbert M, et al. Oxygen uptake during anesthesia washout. Anesthesiology. 1981; 55:256.

Lunn HF. Observations on heat gain and loss in surgery. Guy's Hospital Representative. 1969; 18:117-127.

Morris RH. Influence of ambient temperature on patient temperature during intra-abdominal surgery. Annals of Surgery. 1971; 173:230.

Morris RH. Operating room temperature and the anesthetized, paralyzed patient. Archieves of Surgery. 1971; 102:95-97.

Morris RH, Kumar A. The effect of warming blankets on maintenance of body temperature of the anesthetized, paralyzed adult patient. Anesthesiology. 1972; 35:408-411.

Morris RH, Wilkey BR. The effects of ambient temperature on patient temperature during surgery not involving body cavities. Anesthesiology. 1970; 32:102-107.

Ozuna JM. A study of surgical patient's temperatures. AORN Journal. 1978; 28:240-245.

Newman BJ. Control of accidental hypothermia. Anesthesia. 1971; 26:177-187.

Pflug AE, Aasheim GM, Foster C, et al. Prevention of post-anaesthesia shivering. Canadian Anesthesiology Society Journal. 1978; 25:43-49.

Roe CF, Goldberg MJ, Blair CS, Kinney JM. The influence of body temperature on early postoperative oxygen consumption. Surgery. 1966; 60:85.

Rozien MF, Sohn YL, L'Hommedieu CS, Wylie EJ, Ota MK. Operating room temperature prior to surgical draping: Effect on patient temperature in recovery room. Anesthesia and Analgesia. 1980; 59:852-855.

Tausk HC, Miller R, Roberts RB. Maintenance of body temperature by heated humidification. Anesthesia and Analgesia. 1976; 55:719-723.

Vale RJ. Normothermia: It's place in operative and postoperative care. Anaestesia. 1973; 29:241-245.

Vaughn MS, Vaughn RW, Cork RC. Postoperative hypothermia in adults: Relationship of age, anesthesia, and shivering to rewarming. Anesthesia and Analgesia. 1981; 60:746-751.

Webb GE. Comparison of esophageal and tympanic temperature monitoring during cardiopulmonary bypass. Anesthesia and Analgesia. 1973; 52:729-733.

Whitby JD, Dunkin LJ. Temperature differences in the oesophagus. British Journal of Anaesthesia. 1971; 43:673-675.

Whitby JD, Dunkin LJ. Cerebral, oesophageal and nasopharyngeal temperatures. British Journal of Anaesthesia. 1971; 43:673-675.

Wyon DP, Lidwell OM, Williams REO. Thermal comfort during surgical operations. Journal of Hygeine. 1968; 66:229-248.

# APPENDIX A

# CONSENT FORM

## EXPLANATION OF PROCEDURE TO THE PATIENT

The purpose of this study is to assess the effectiveness of two externally applied heating techniques, warmed intravenous fluids and a heating blanket, on patient temperature during surgery.

It is a common occurrence when body temperature drops slightly during a surgical procedure. The body temperature tends to drop because the operating room is cool, intravenous fluids are cool, the operating room table is cool, and a part of your body will be exposed for the surgical procedure.

A decreased temperature, though a common occurrence during general anesthesia (being put to sleep for a surgical procedure), is of concern to the anesthetist. It has been shown that a patient with a temperature within the normal range at the completion of a surgical procedure will have a smoother, less complicated recovery from anesthesia.

For this study, you will be randomly assigned to one of four groups:

Group I - will undergo surgery without an externally applied heating technique.

Group II - will undergo surgery with one externally applied heating technique: warmed intravenous fluids will be administered during surgery.

Group III - will undergo surgery with one externally applied heating technique: a warmed heating blanket placed on the operating room table.

Group IV - will undergo surgery with a combination of two externally applied heating techniques: warmed intravenous fluid administration and a warmed heating blanket on the operating room table will be used.

Upon arrival in the operating room, an intravenous infusion of D5LR will be started with an intravenous catheter, and heart beat and blood pressure will be routinely monitored.

After anesthesia is administered, an esophageal (the passageway from the mouth to the stomach) temperature probe will be inserted. The esophageal temperature probe will be removed before the anesthesia is finished, and there should be no discomfort postoperatively from the placement of this probe.

The conduct of anesthesia will be the same regardless of whether or not you participate in this study. If you agree to participate in this study, please sign your name and the date on the lines below. Confidentiality will be maintained at all times. If, at any time during the anesthesia, your safety is compromised, the study will be discontinued.

I understand that I may at any time, prior to the anesthetic, revoke my consent from the study without prejudice. I understand that in the event of any physical and/or mental injury resulting from my participation in this research project, Virginia Commonwealth University will not offer compensation or medical treatment.

Name:_____

Date:_____

# APPENDIX B

# DATA COLLECTION FORM

DATA COLLECTION FORM

SUBJECT #....._____ STUDY GROUP #....._____

GENDER.....__M___F__ SURGICAL PROCEDURE_____

AGE....._____ ASA CLASSIFICATION_____

WT....._____ BREATHING CIRCUIT._____

HT....._____ FRESH GAS FLOW...._____

BODY SRRFACE AREA....._____ ELECTRO-COAG.....___Y____N___

PRIMARY ANESTHETIC AGENT

( ) FORANE

( ) ETHRANE

( ) HALOTHANE

( ) NARCOTIC

| | BASELINE | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 |
|---|---|---|---|---|---|---|---|---|---|
| ESOPHAGEAL TEMP | | | | | | | | | |
| AMBIENT TEMP | | | | | | | | | |
| BLOOD WARMER TEMP | | | | | | | | | |
| WARMING BLANKET TEMP | | | | | | | | | |

IV FLUIDS ADMINISTERED: 30 _____cc 90 _____cc

60 _____cc 120 _____cc

# APPENDIX C

# DESCRIPTIVE STATISTICS

Descriptive Statistics

Group 1: Control (n=7)

| Variable | Mean | S. E. | Range |
|---|---|---|---|
| Age (years) | 35.1 | 3.5 | 22-44 |
| Height (M) | 1.79 | 0.02 | 1.68-1.85 |
| Weight (Kg) | 71.0 | 1.5 | 68-79 |
| BSA (M2) | 1.89 | 0.03 | 1.81-2.02 |
| Esophageal Temperature: | | | |
| Baseline | 36.1 | 0.1 | 35.9-36.5 |
| T120 | 35.6 | 0.2 | 35.0-36.3 |
| Ambient Temperature (C) | 20.4 | 0.2 | 19.5-21.0 |
| IV Fluids (ml) | 1300. | 226. | 600-2000 |
| IV Fluids (ml/kg) | 18.3 | 3.2 | 8.8-29.4 |

Group 2: Warmed Crystalloid (n=7)

| Variable | Mean | S. E. | Range |
|---|---|---|---|
| Age (years) | 49.8 | 5.4 | 28-63 |
| Height (M) | 1.74 | 0.04 | 1.55-1.88 |
| Weight (Kg) | 75.0 | 6.7 | 48-107 |
| BSA (M2) | 1.88 | 0.09 | 1.44-2.20 |
| Esophageal Temperature: | | | |
| Baseline | 36.2 | 0.1 | 35.9-36.6 |
| T120 | 36.0 | 0.1 | 35.6-36.5 |
| Ambient Temperature (C) | 20.1 | 0.2 | 19.5-20.5 |
| IV Fluids (ml) | 1250. | 302. | 550-3000 |
| IV Fluids (ml/kg) | 17.0 | 4.2 | 9.3-41.7 |

Group 3: Warming Blanket (n=7)

| Variable | Mean | S. E. | Range |
|---|---|---|---|
| Age (years) | 44.0 | 5.9 | 22-63 |
| Height (M) | 1.80 | 0.02 | 1.73-1.90 |
| Weight (Kg) | 75.7 | 5.9 | 57-104 |
| BSA (M2) | 1.94 | 0.07 | 1.69-2.26 |
| Esophageal Temperature: | | | |
| Baseline | 36.1 | 0.1 | 35.6-36.7 |
| T120 | 35.7 | 0.4 | 34.2-37.4 |
| Ambient Temperature (C) | 19.8 | 0.2 | 19.0-20.5 |
| IV Fluids (ml) | 1386. | 139. | 950-2000 |
| IV Fluids (ml/kg) | 18.8 | 2.0 | 9.1-27.0 |

Group 4: Warmed Crystalloid + Warming Blanket (n=7)

| Variable | Mean | S. E. | Range |
|---|---|---|---|
| Age (years) | 59.7 | 3.7 | 45-75 |
| Height (M) | 1.70 | 0.03 | 1.57-1.78 |
| Weight (Kg) | 71.8 | 3.3 | 60-85 |
| BSA (M2) | 1.83 | 0.06 | 1.60-2.03 |
| Esophageal Temperature: | | | |
| Baseline | 36.2 | 0.1 | 35.9-36.5 |
| T120 | 36.3 | 0.1 | 36.1-36.6 |
| Ambient Temperature (C) | 20.1 | 0.2 | 19.0-21.0 |
| IV Fluids (ml) | 1378. | 153. | 800-1900 |
| IV Fluids (ml/kg) | 19.5 | 2.3 | 9.4-26.8 |

# APPENDIX D

# RAW DATA

RAW DATA: GROUP 1 (CONTROL)

| | Baseline | 15 min. | 30 min. | 45 min. | 60 min. | 75 min. | 90 min. | 105 min. | 120 min. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 35.9 | 35.7 | 35.7 | 35.6 | 35.4 | 35.4 | 35.3 | 35.3 | 35.0 |
| 2 | 36.0 | 35.7 | 35.6 | 35.6 | 35.7 | 35.7 | 35.7 | 35.9 | 35.9 |
| 3 | 36.4 | 35.8 | 35.8 | 35.6 | 35.4 | 35.4 | 35.4 | 35.4 | 35.4 |
| 4 | 36.2 | 36.0 | 35.9 | 35.8 | 35.7 | 35.7 | 35.7 | 35.7 | 35.7 |
| 5 | 35.9 | 35.7 | 35.6 | 35.4 | 35.4 | 35.3 | 35.3 | 35.3 | 35.3 |
| 6 | 36.1 | 36.2 | 36.3 | 36.4 | 36.3 | 36.4 | 36.3 | 36.3 | 36.3 |
| 7 | 36.5 | 36.2 | 35.9 | 35.6 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 |
| N= | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| $\bar{x}$= | 36.1 | 35.9 | 35.8 | 35.7 | 35.6 | 35.6 | 35.6 | 35.6 | 35.6 |
| SD= | .244 | .231 | .243 | .324 | .325 | .373 | .385 | .368 | .426 |
| RANGE= | .6 | .5 | .7 | 1 | .9 | 1.1 | 1 | 1 | 1.3 |
| LOW= | 35.9 | 35.7 | 35.6 | 35.4 | 35.4 | 35.3 | 35.3 | 35.3 | 35.0 |
| HIGH= | 36.5 | 36.2 | 36.3 | 36.4 | 36.3 | 36.4 | 36.3 | 36.3 | 36.3 |

RAW DATA: GROUP 2 (WARMED CRYSTALLOID)

| | Baseline | 15 min. | 30 min. | 45 min. | 60 min. | 75 min. | 90 min. | 105 min. | 120 min. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 36.6 | 36.2 | 36.0 | 35.9 | 35.8 | 35.8 | 35.8 | 35.8 | 35.9 |
| 2 | 36.4 | 35.8 | 35.9 | 36.0 | 36.2 | 36.4 | 35.5 | 35.5 | 35.5 |
| 3 | 36.2 | 36.0 | 35.8 | 35.8 | 35.7 | 35.8 | 35.6 | 35.6 | 35.6 |
| 4 | 35.9 | 35.9 | 35.9 | 35.7 | 35.6 | 35.8 | 35.9 | 35.8 | 35.9 |
| 5 | 36.5 | 36.4 | 36.3 | 36.4 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 |
| 6 | 36.1 | 36.0 | 35.8 | 35.8 | 35.8 | 35.6 | 35.4 | 35.5 | 35.6 |
| 7 | 36.1 | 36.1 | 36.0 | 35.8 | 35.8 | 35.8 | 35.9 | 36.1 | 36.1 |
| N= | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| $\bar{x}$= | 36.3 | 36.1 | 36.0 | 36.0 | 35.9 | 36.0 | 35.8 | 35.8 | 35.9 |
| SD= | .251 | .199 | .172 | .234 | .319 | .346 | .365 | .364 | .350 |
| RANGE= | .7 | .6 | .5 | .7 | .9 | .9 | 1.1 | 1 | 1 |
| LOW= | 35.9 | 35.8 | 35.8 | 35.7 | 35.6 | 35.9 | 35.4 | 35.5 | 35.5 |
| HIGH= | 36.6 | 36.4 | 36.3 | 36.4 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 |

RAW DATA: GROUP 3 (WARMING BLANKET)

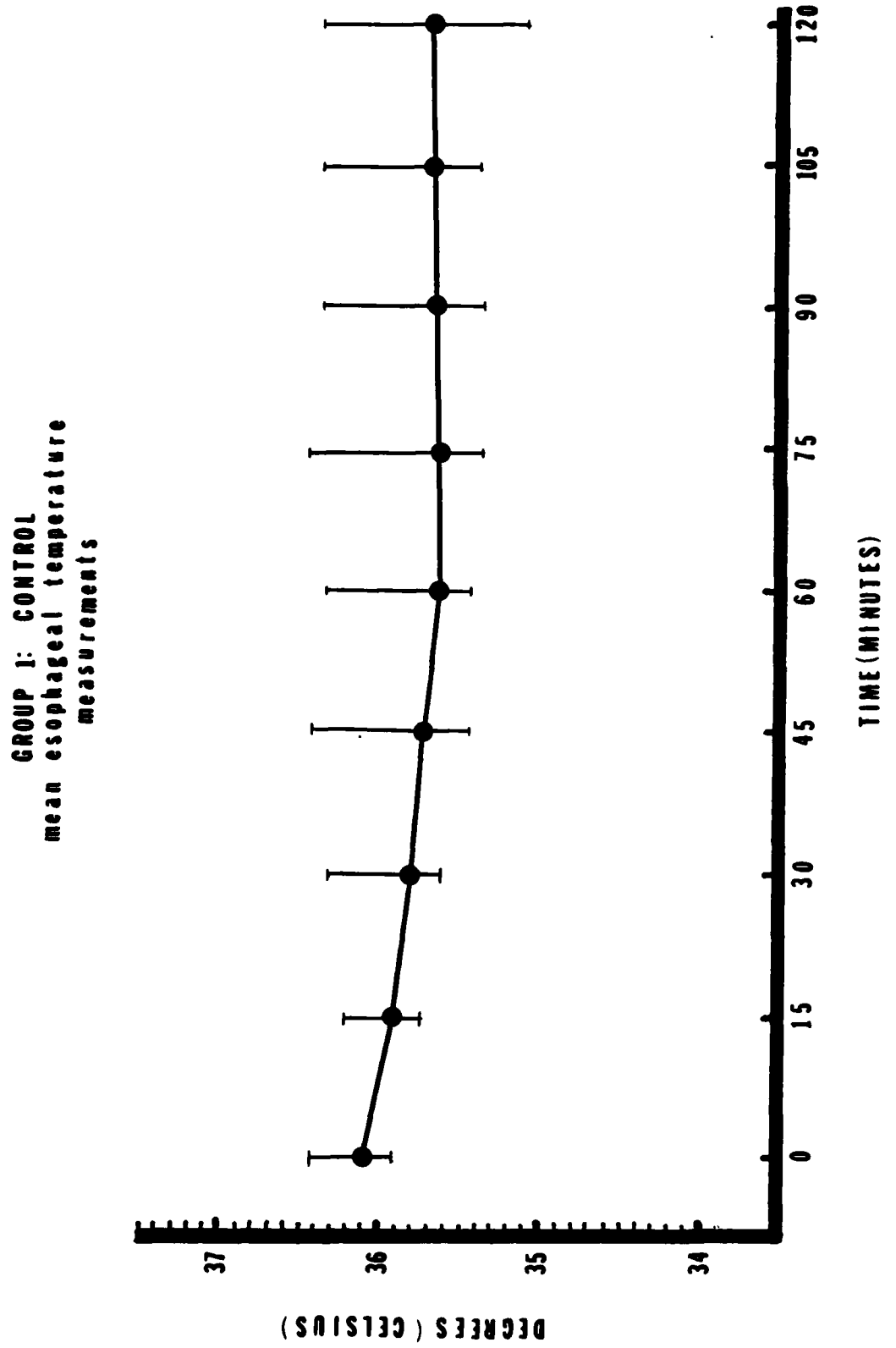
| | Baseline | 15 min. | 30 min. | 45 min. | 60 min. | 75 min. | 90 min. | 105 min. | 120 min. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 36.0 | 35.8 | 35.7 | 35.6 | 35.5 | 35.6 | 35.4 | 35.6 | 35.6 |
| 2 | 35.9 | 35.7 | 35.6 | 35.7 | 35.7 | 35.8 | 35.9 | 35.8 | 35.9 |
| 3 | 36.4 | 36.0 | 35.9 | 36.0 | 35.9 | 35.9 | 35.7 | 35.7 | 35.7 |
| 4 | 36.2 | 36.0 | 36.0 | 35.9 | 35.9 | 35.8 | 35.9 | 35.8 | 35.7 |
| 5 | 35.7 | 34.5 | 34.4 | 34.2 | 34.3 | 34.3 | 34.2 | 34.2 | 34.2 |
| 6 | 35.6 | 35.6 | 35.7 | 35.6 | 35.5 | 35.6 | 35.6 | 35.7 | 35.7 |
| 7 | 36.7 | 36.9 | 37.1 | 37.2 | 37.3 | 37.4 | 37.4 | 37.4 | 37.4 |
| N= | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| $\bar{x}$ | 36.1 | 35.8 | 35.8 | 35.7 | 35.7 | 35.8 | 35.7 | 35.7 | 35.7 |
| SD= | .390 | .711 | .791 | .879 | .883 | .903 | .941 | .927 | .929 |
| RANGE= | 1.1 | 2.4 | 2.7 | 3 | 3 | 3.1 | 3.2 | 3.2 | 3.2 |
| LOW= | 35.6 | 34.5 | 34.4 | 34.2 | 34.3 | 34.3 | 34.2 | 34.2 | 34.2 |
| HIGH= | 36.7 | 36.9 | 37.1 | 37.2 | 37.3 | 37.4 | 37.4 | 37.4 | 37.4 |

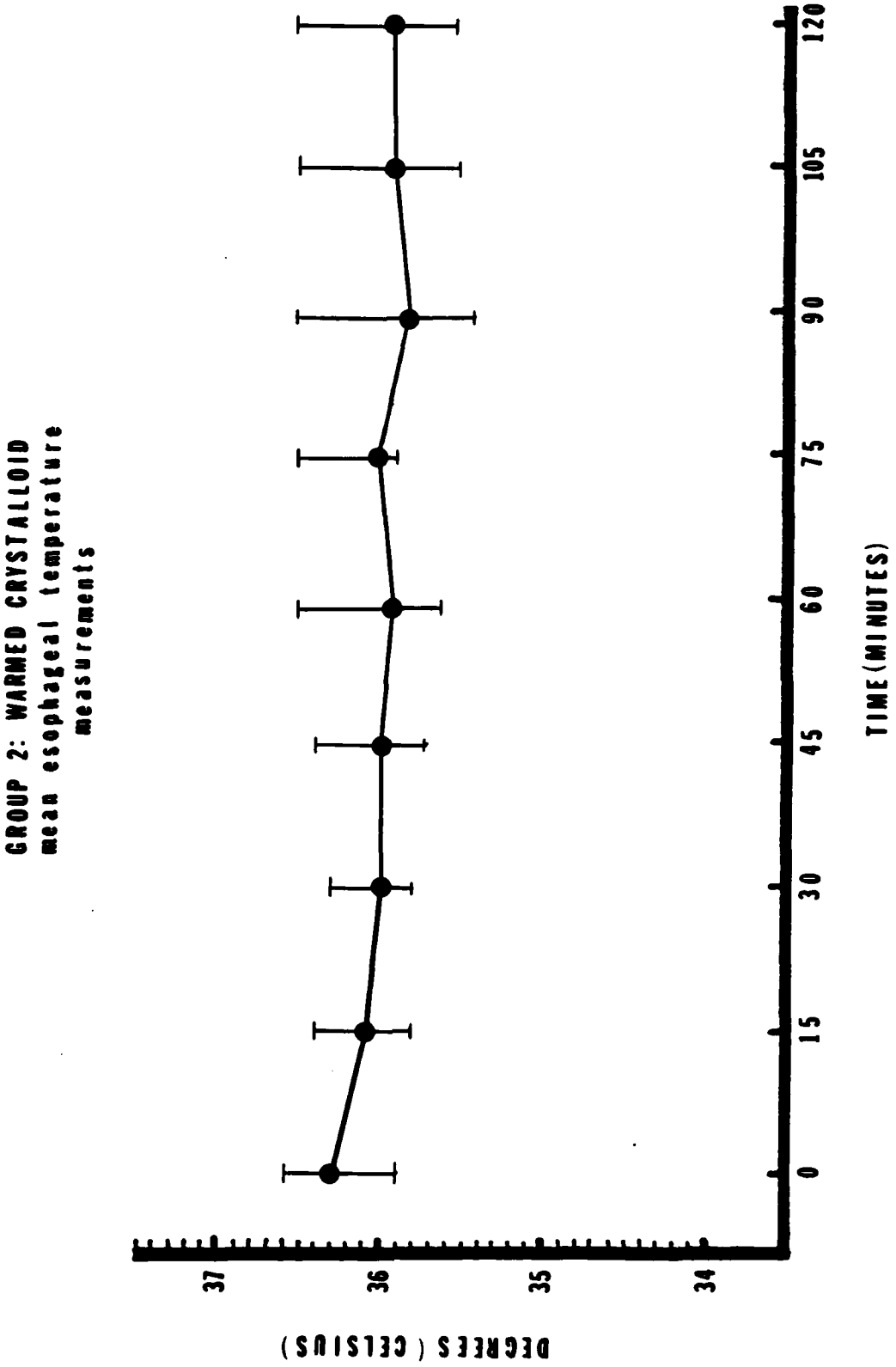
RAW DATA: GROUP 4 (WARMED CRYSTALLOID + WARMING BLANKET)

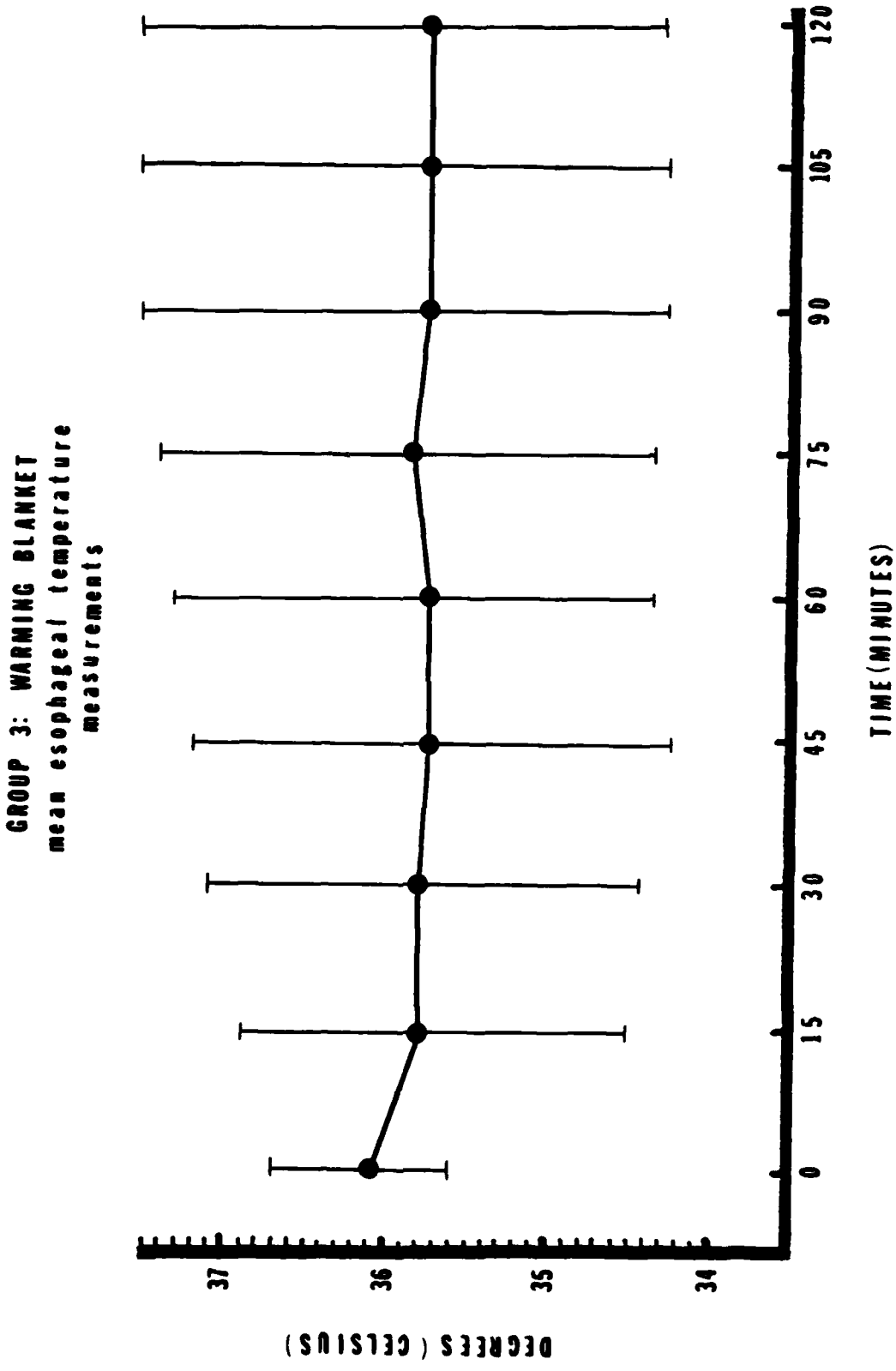
| | Baseline | 15 min. | 30 min. | 45 min. | 60 min. | 75 min. | 90 min. | 105 min. | 120 min. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 36.5 | 36.3 | 36.3 | 36.0 | 36.1 | 36.1 | 36.3 | 36.3 | 36.5 |
| | 35.9 | 35.9 | 35.7 | 35.7 | 35.9 | 35.8 | 35.9 | 36.1 | 36.1 |
| 3 | 36.4 | 36.3 | 36.2 | 36.2 | 36.2 | 36.3 | 36.4 | 36.5 | 36.6 |
| 4 | 35.9 | 35.8 | 35.8 | 35.9 | 36.0 | 36.1 | 36.1 | 36.2 | 36.2 |
| 5 | 36.2 | 36.3 | 36.3 | 36.2 | 36.1 | 36.1 | 36.0 | 36.1 | 36.1 |
| 6 | 36.1 | 36.0 | 36.0 | 36.0 | 36.0 | 36.1 | 36.1 | 36.2 | 36.4 |
| 7 | 36.2 | 36.1 | 36.1 | 36.1 | 36.1 | 36.2 | 36.2 | 36.4 | 36.5 |
| N= | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| $\bar{x}$= | 36.2 | 36.1 | 36.1 | 36.0 | 36.1 | 36.1 | 36.1 | 36.3 | 36.3 |
| SD= | .229 | .208 | .237 | .177 | .098 | .153 | .172 | .151 | .207 |
| RANGE= | .6 | .5 | .6 | .5 | .3 | .5 | .5 | .4 | .5 |
| LOW= | 35.9 | 35.8 | 35.7 | 35.7 | 35.9 | 35.8 | 35.9 | 36.1 | 36.1 |
| HIGH= | 36.5 | 36.3 | 36.3 | 36.2 | 36.2 | 36.3 | 36.4 | 36.5 | 36.6 |

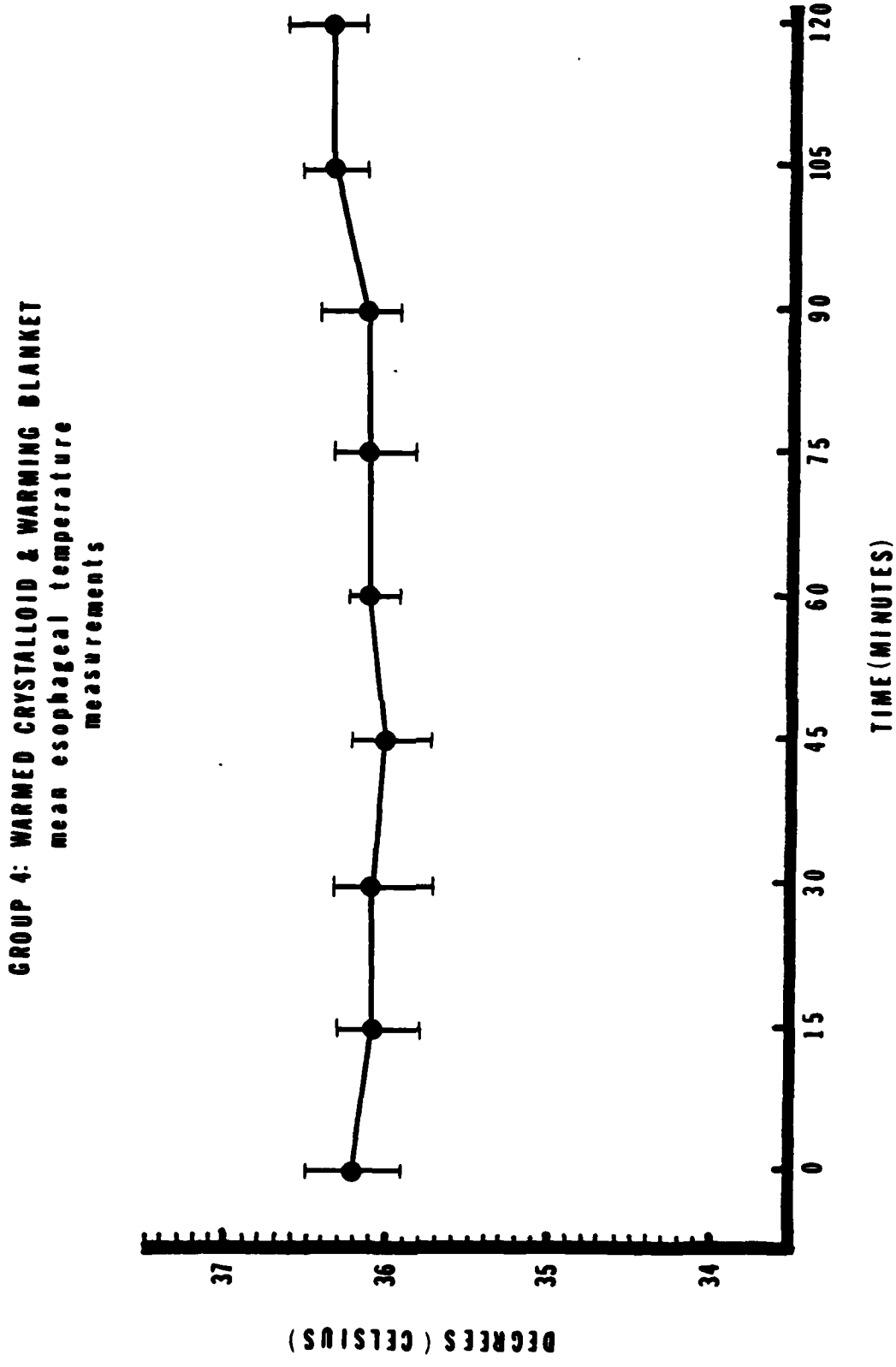
# APPENDIX E

## MEAN ESOPHAGEAL TEMPERATURE MEASUREMENTS


GROUP 1: CONTROL
mean esophageal temperature
measurements
37
36
35
34
DEGREES (CELSIUS)
0
15
30
45
60
75
90
105
120
TIME(MINUTES)


GROUP 2: WARMED CRYSTALLOID
mean esophageal temperature
measurements
DEGREES (CELSIUS)
37
36
35
34
0
15
30
45
60
75
90
105
120
TIME(MINUTES)


GROUP 3: WARMING BLANKET
mean esophageal temperature
measurements
DEGREES (CELSIUS)
37
36
35
34
0
15
30
45
60
75
90
105
120
TIME(MINUTES)


GROUP 4: WARMED CRYSTALLOID & WARMING BLANKET
mean esophageal temperature
measurements
DEGREES (CELSIUS)
37
36
35
34
0
15
30
45
60
75
90
105
120
TIME(MINUTES)

# VITA

Robert Eugene McCain was born on July 22, 1947, in Harvey, Illinois, and is an American citizen. He graduated from Thornton Township High School. He received a Bachelor of Science in Nursing from Incarnate Word College, San Antonio, Texas, in 1979. He received a Diploma in Nursing from Watts Hospital School of Nursing, Durham, North Carolina, in 1973.

He is a captain in the United States Air Force Nurse Corps. He has worked as a staff oncology and infectious disease nurse at Wilford Hall Medical Center, Lackland Air Force Base, San Antonio, Texas. He has worked as an aeromedical evacuation flight nurse at Scott Air Force Base, Belleville, Illinois.


FILM